INDOOR AIR QUALITY ASSESSMENT

Hastings Elementary School
111 East Main Street
Westborough, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of a parent and the Westborough school department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Hastings Elementary School (HES), 111 East Main Street, Westborough, MA.

The school was visited by Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, on November 15 & 16, 2001 and on January 10, 2002, to conduct an indoor air quality assessment. Cory Holmes, Environmental Analyst of the ER/IAQ Program, and Suzan Donahue, BEHA Research Analyst were present for the November 15 visit. BEHA staff were also accompanied by Les Olsen, Facilities Manager for the Westborough School Department, and Bruce Trettor of the Hastings School Committee, for portions of the assessment on November 15, 2001.

The school is a single story brick/concrete building constructed in 1970. Two portable classrooms were added in 1999. The school was originally designed to have an open classroom plan, but is currently set up as four “pods” that are designated by student grade level. Each pod consists of 6 classrooms that are centered on an outdoor courtyard. Fresh air for the ventilation system is drawn into each classroom from the courtyard through fresh air intakes on the exterior walls. Each pod also has several small rooms, which were originally designed for storage. A few of these rooms are currently being used for classroom space. The kindergarten classrooms are located in a section of the building south of the pod classrooms and are not in a “pod” configuration. A library, cafeteria, kitchen, and office space are located in the section of the building. A gymnasium and a mechanical room exist in the north section of the building. The school houses pre-kindergarten through third grade.

The Westborough School Department provided BEHA staff with copies of reports, letters and memorandum related to the IAQ problems at the HES. From these reports, the HES appears to have a long history of indoor air quality concerns and attempts by school officials to address those concerns.. As reported by school officials, the building experienced substantial water damage from a leaking roof (personal communication with Les Olson, Westborough School Department). As a result of concerns included in a summary of indoor air quality complaints (WBOH, 1991), an indoor air quality study was conducted to assess the HES by a consultant, Honeywell Indoor Air Quality Diagnostics, in 1990. This consultant recommended the following remediation actions:

1. Cleaning of classroom unit ventilators (univents);
2. Recalibration of univent controls;
3. Rebalancing of the univent system so that classrooms are "positively pressurized";
4. Upgrading the efficiency of univent filters;
5. Restoring univent automatic control function;
6. Cleaning of exhaust grilles;
7. Cleaning of the heating, ventilating and air conditioning (HVAC) system for the cafetorium, library and administrative areas;
8. Checking drain pans in univents for proper drainage;
9. Repairing roof leaks;
10. Replacing water-damaged ceiling tiles;

11. Increasing the exhaust airflow rate for the smoking lounge (no longer in existence) (HIAQD, 1991).

Mold odors in the HES recurred several years after this initial investigation. A consultant was hired to conduct carpet dust sampling (LEA, 1997). This consultant recommended steam cleaning of carpet or removal and indicated that "elevated levels of moisture {were} coming from below the carpeting…" (LEA, 1997). The carpeting originally installed in 1971, was removed (personal communication with Les Olson, Westborough School Department). In 1998, air testing, slab moisture content, bioaerosol sampling and HVAC system evaluation were conducted by a third consultant (LFR, 1998). This consultant recommended the following remediation actions:

1. Cleaning of classroom unit ventilators (univents);
2. Replacement filters;
3. Balancing ventilation system;
4. Discarding water damaged carpet;
5. Use of a portable dehumidifier to reduce moisture in the building when relative humidity exceeds 60%.

Further air testing for relative humidity and carbon dioxide levels were measured in multiple areas within the building on December 8-12, 1997 (ASI, 1998). Carbon dioxide levels were reported as "within normal range". Relative humidity levels "were not elevated" in classrooms. Elevated moisture readings in the kitchen and cafeteria were attributed to cooking (ASI, 1998). On January 13, 1999, air monitoring was conducted by a fourth consultant, Clayton Environmental Consultants (CEC). This consultant recommended:

1. Adjust the ventilation system to deliver 20 cubic feet per minute (cfm) (or 15 cfm where appropriate) of fresh air;
2. Reduce the amount of exhaust ventilation to maintain positive pressurization of the building;
3. Modify restroom exhaust vents to operate continuously during occupancy;
4. Maintain negative pressure to exhaust air from the incinerator maintenance and storage areas;
5. Conduct further assessment to confirm that recommendations 1-4 positively influence indoor air quality;
6. Check the building envelope for water penetration;
7. Have water damaged materials evaluated for microbial contamination;
8. Eliminate moisture sources;
9. Remove microbiologically contaminated non-porous materials (CEC, 1999a).

Further air sampling for fungi found fungal concentrations normal during sampling on April 8, 1999 (CEC, 1999b). That same year, a fifth consulting firm, Environmental Health and Engineering (EH&E), was retained to evaluate the indoor air quality at the HES. This consultant made the following findings/recommendations:

1. The HES is negatively pressurized, which is drawing in air, particles and other pollutants into classrooms;
2. Fungal growth was found on mechanical room addition pipe insulation;
3. Univents were dirty;

4. Fresh air intakes at ground level were overgrown with plants, resulting in possible entrainment of pollen or plant fragments. It was recommended to install concrete in front of univent fresh air intakes;
5. Increase cleaning and decrease using ceiling grids to hang artwork;
6. Remove debris from stacks on roof (EH&E, 1999a.).

In an effort to further characterize possible contaminants present in the building, a variety of environmental air testing and groundwater analysis were proposed by the consultant (EH&E, 1999b). No unusual concentrations of endotoxins or volatile organic compounds (VOCs) were noted (EH&E, 1999c). Test wells were drilled to sample groundwater around the perimeter and below the building's concrete slab. All monitoring wells had VOC levels below laboratory detection level, indicating no groundwater contamination (EH&E, 1999c). Negative pressurization of the HES by the exhaust ventilation system was confirmed by tracer gas analysis. As a result of this round of testing, the consultant made several observations:

1. Balancing of the system by a certified balancer was in progress to reverse the negative pressure identified in the HES;
2. The ventilation system was cleaned;
3. The ventilation system was readjusted;
4. A contractor was hired to remove/replace pipe insulation in the mechanical room;
5. Plants were removed from the courtyards.

The pod courtyards were also paved with concrete (see Picture 1). EH&E conducted a follow-up study at the HES on December 20, 1999. Filters in univents were found to be short. The HES was found to be positively pressurized. Carbon dioxide levels were reported by EH&E to be "generally adequate" (EH&E, 2000). Air monitoring for particulate found levels below the US EPA National Ambient Air Quality Standard for particles of a diameter less than 10 micrometers for a 24-hour exposure (EH&E, 2000). A follow-up study for fungal growth was conducted by EH&E on October 23, 2001, and no sources of fungal growth were identified in the HES (EH&E, 2001). Concerns from parents and school staff regarding buckling floor tiles in several classrooms were also voiced prompted further investigation. The manufacturer of the floor tiling and adhesive collected samples of these materials for chemical analysis. Reportedly, moisture analysis found no unusual concentration of moisture in the floor slab beneath the buckling tiles. However, the moisture analysis report was not available at the time of the writing of this IAQ report.

The Westborough School Department (WSD) has completed a number of capital and repair projects to improve conditions in the school. These efforts include extensive repair and maintenance on the school's heating, ventilation and air conditioning (HVAC) systems, replacing carpet with tile, roof repairs and interior renovations in a number of areas.

Methods

As previously noted BEHA staff visited the school on November 15 and 16, 2001 and January 10, 2002. Air tests for carbon dioxide, temperature and relative humidity using a TSI, Q-Trak, IAQ Monitor, Model 8551. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). Measurements were taken at several locations inside the building believed to be impacted by odors, as well as outside for comparison purposes.

Results

This school has a student population of approximately 585 and a staff of approximately 100. Tests were taken during normal operations at the school and results appear in Tables 1-13.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated slightly above 800 parts per million parts of air (ppm) in fifteen out of forty-eight areas on November 15, 2002 and seven out of thirty four areas on November 16, 2002, indicating adequate fresh air ventilation in most areas of the school.

Fresh air in classrooms is supplied by a unit ventilator (univent) system. Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit (see Figure 1). Fresh air and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents were operating in classrooms throughout the school, however obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns were seen in many classrooms (see Picture 2). In order for univents to provide fresh air as designed, intakes must remain free of obstructions and allowed to operate while rooms are occupied.

Fresh air in interior areas is provided by rooftop motorized fresh air intakes that are connected by ductwork to air-handling units (AHUs) located in interior rooms. The rooftop motorized fresh air intakes act in concert with the AHUs to provide fresh air to interior areas via ductwork to ceiling or wall-mounted supply vents. As with the univents, the AHUs were operating during the assessment.

Exhaust ventilation is provided by a ducted system, with the return grille located in the ceiling of the coat closets in each classroom (see Picture 3). Classroom air is drawn into the coat closet from the classroom via undercut closet doors. These vents were designed to remove moisture/odors from the closets. This exhaust system was operational, but a weak draw of air was noted in a number of rooms. It was reported by school officials that exhaust capabilities were reduced to prevent the negative pressurization of classrooms, which has been a well-documented problem in the past (EH&E, 1999a; CEC, 1999a; HIAQD, 1991). The location of these closet vents also allows them to be easily blocked by stored materials. In order to function properly, these vents must remain free of obstructions.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The last balancing of these systems was performed in

1999. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Temperature measurements ranged from 70° F to 76° F, which were within the BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ° F to 78 ° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Heat complaints were reported in the computer room, which contained approximately a dozen computers and a number of printers. The computer room is located in one of the converted storage rooms previously mentioned, with no windows or air conditioning. Computer equipment and printers can generate waste heat while they operate, which can build up over time in an area without adequate ventilation. Lack of ventilation can lead to poor air quality and comfort complaints. While temperature readings slightly above the recommended range are generally not a health concern, increased temperature can affect the relative humidity in a building. It was reported that the computer room is scheduled to be relocated to an air conditioned classroom prior to the start of the forthcoming school year (2002-2003).

The relative humidity in the building was very close to or within the BEHA recommended comfort range in all areas sampled. Relative humidity measurements ranged from thirty-six to fifty-eight percent. The BEHA recommends that indoor air relative humidity is comfortable in a range of forty to sixty percent. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Of note however, is that the relative humidity measured in the ESL room exceeded outdoor measurements by sixteen percent. The increase in relative humidity can indicate that the exhaust system alone is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). Moisture removal is important since the sensation of heat increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperatures rise, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. Removal of moisture from the air is important since no windows are in this room. Moisture removal from the air, however, can have some negative effects. As mentioned above, the sensation of dryness and irritation is common in a low relative humidity environment. Relative humidity levels in the building would be expected to drop during the winter months due to heating. Humidity is more difficult to control during the winter heating season.

Microbial/Moisture Concerns

As reported by Westborough school officials, the building had experienced efflorescence in interior walls of the building. As an example, the interior wall in the gymnasium storeroom has efflorescence at a height several feet above the floor. Efflorescence is caused by water penetration through brick, dissolving minerals within the brick as it flows through. The water evaporates leaving a dry white residue. While efflorescence is a characteristic sign of water penetration, it is not mold growth. The presence of efflorescence can indicate that rainwater is penetrating through the exterior wall system.

In order to explain how water penetration occurs through exterior wall systems, the following concepts concerning moisture and wall systems must be understood.

1. Brick, cement and mortar contain water, which allows moisture movement through these materials;
2. Wind driven rains increase water penetration through brick, cement and mortar;
3. Brick, cement and mortar must dry in a timely fashion to prevent opportunistic microbial growth; and
4. Gravity will direct water in a building towards the ground.

Exterior wall systems should be designed to prevent moisture penetration into the building interior through the use of a drainage plane within the wall system to redirect water outdoors and allow for building components to dry. An exterior wall system should have the following components in order to drain water (see Figure 2):

- An exterior curtain wall forming the outer cladding of the building.
- Behind the curtain wall is an air space that allows for water to drain downward and allow for the exterior cladding system to dry.
- Holes at the base of the curtain wall that allow for water drainage (called weep holes).
- Opposite the exterior wall, across the air space, is a continuous, water-resistant material adhered to a wall (the back up wall) which forms the drainage plane. The purpose of the drainage plane is to prevent moisture that crosses the air space from penetrating into interior building systems and to direct that moisture downward to the weep holes. The drainage plane can consist of a number of

water-resistant materials, such as tarpaper or in newer buildings, plastic wraps. The drainage plane should be continuous.

- Where breaks exist in the drainage plane (e.g., window systems, door systems, and univent fresh air intakes), the penetrations have materials added (e.g. copper flashing) to direct water to weep holes.

If the drainage plane is discontinuous, missing flashing or lacking an air space, rainwater may accumulate inside the wall cavity and lead to moisture penetration into the building.

In order to ascertain the condition of the exterior wall system, the fresh air intake grill for a univent was removed to check for the presence of a sheet metal duct connecting the grill to the univent. No such duct existed for this univent. Fresh air is drawn through the grill through the exterior wall to the air intake opening for the univent. No flashing to direct rainwater exists in this intake. The apparent airspace between the exterior wall and drainage plane was sealed with concrete (see Picture 4). The interior wall of brick forming the fresh air intake opening was coated with efflorescence, indicating water penetration (see Picture 5).

The interior of the wall cavity was examined through a hole cut for the installation of an exhaust vent in an interior courtyard (see Picture 6). Concrete used to build the exterior brick wall appeared to transverse the air space, creating a bridge of mortar in contact with the backing wall. It does not appear that the backing wall has a visible physical barrier that would serve as a drainage plane. Examination of the blueprints for this building indicates that a limited drainage plane of cloth was installed. These mortar bridges that cross the air space form a discontinuous drainage plane, which then creates a honeycomb effect, trapping water in the upper section of the walls. By trapping water, this honeycomb configuration would tend to keep water at the high section of walls creating the efflorescence pattern seen in the gymnasium storeroom. This possible source of moisture penetration can create further problems if it is present within the air stream of the univent ventilators. Without a sleeve to isolate the air stream from the wall system, odors and other materials can then be drawn into univents. This problem would be expected to occur during or the day after rainstorms that wet the exterior wall systems.

As reported by school officials, the ventilation system was converted to a gas heat/air conditioned system from the original electric univents. The coils were replaced, a drip pan/condensation drain system was installed, and the heating system was replaced. Of note is the lack of insulation on univent cabinet walls and the drip pans that are in contact with chilled air during the operation of the ventilation system during warm months.

When warm, moist air passes over a surface that is colder than the air, water condensation can collect on the cold surface. Over time, water droplets can form, which can then drip from a suspended surface. For this reason, HVAC systems are equipped with drainage systems beneath cooling coils to drain condensate as moist outdoor air is cooled. Univents are equipped with on-the spot constructed metal drip pans. These drain pans would tend to distort shape, therefore preventing draining and resulting in a pooling effect. BEHA staff poured approximately 12 fluid ounces of water into a univent drip pan to observe the rate of drainage. Most of this water appeared to pool in the drain pan, with minimal drainage.

In every univent examined, a characteristic pattern of corrosion (rust) was noted, indicating that water accumulates within each pan (see Picture 7). With the temperature of the drip pan reduced by prolonged contact with condensation, moist air introduced by the univent can then generate condensation on the underside of the drip pan, which can then drip onto fan housings and univent filters. Chilled air also reduces the temperature of the side-walls of the univent air-handling chamber, subsequently resulting in condensation generation inside the control and utility chambers. In order to avoid the generation of moisture, the underside of drip pans and the exterior walls of the univent air-handling chamber can be insulated.

All univents examined lacked insulation. Signs of dried condensation were noted on the underside of drip pans (see Picture 8), inside univent control chambers (see Picture 9) and possible subtle staining of library carpets (see Picture 10) was observed. This condition was also observed in carpeting immediately adjacent to library univents. Accumulated dust in univent control cabinets, univent filters and carpeting may all serve as mold growth media if moistened for extended periods of time. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged, porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy materials is not recommended. In addition, water coolers/fountains were located over/on wall-to-wall carpeting in various areas. Spills or overflow from usage can result in wetting of the carpet, which can lead to mold growth.

Water vapor was observed collecting within a number of double-paned glass windows. This condition indicates that the window’s water seal is no longer intact.

Water penetration through window frames can lead to mold growth under certain conditions. Room 105 had two broken windows. Repairs of window leaks are necessary to prevent further water penetration. Repeated water damage can result in mold colonization of window frames, curtains and items stored on windowsills.

Several classrooms contained a number of plants. Plant soil and drip pans can serve as sources of mold growth. Plants should also be located away from univents and exhaust ventilation to prevent aerosolization of dirt, pollen or mold. Two aquariums were observed in the building. When not in use, aquariums should be properly cleaned to prevent bacterial growth, mold growth and nuisance odors.

In a number of classrooms, spaces between the sink countertop and backsplash were noted. A leaking faucet was noted in the health suite. Repeated leakage or improper drainage/overflow can lead to water penetration of countertop wood, the cabinet interior and behind cabinets. Like other porous materials, if these materials become wet repeatedly, they can provide mediums for mold growth.

Other Concerns

Concerns were raised about possible chemical exposure from materials that appear to be seeping from seams in classroom floor tiles (see Pictures 11 and 12). In an effort to identify whether chemicals [specifically volatile organic compounds (VOCs)] were becoming aerosolized from these materials, air monitoring for aerosolized materials was conducted on January 10, 2002 after school hours. Total volatile organic compounds (TVOCs) are groups of substances containing carbon that have the ability to evaporate at room temperature. Frequently, exposure to low levels of TVOCs may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. If a chemical were present that was evaporating at room temperature from tile adhesive, the most likely materials would be TVOCs. A PID was attached to a luggage rack to measure TVOC concentrations at a height of 4 inches above floor blemishes. An outdoor air sample in the school parking lot the day of sampling was taken for comparison value (TVOC concentration outdoors was measured at 0.4 ppm). Indoor TVOC concentrations either matched or were below outdoor measured concentrations, indicating that there was no TVOC emission from the floor blemishes.

According to school officials, the manufacturer of the floor system (tile and adhesive) conducted sampling on floor materials. This report indicates that the materials butyl cellusolve (ethylene glycol monobutyl ether), butyl carbitol, diethylene glycol, monobutyl ether and dipropylene glycol were measured within the black adhesive residue (Stadden, D.R. and Kolibab, S.M., 2002). Each of these compounds is a glycol-related compound. They are also heavier than air and evaporates at a rate slower than water at room temperature. Each chemical is associated with irritation of the skin, eyes or respiratory system, however these substances would not be expected to evaporate in appreciable amounts to cause health effects in exposed individuals, as confirmed by TVOC testing conducted by BEHA staff. This lack of airborne concentration of these materials was confirmed by the air monitoring conducted by BEHA staff, which measured TVOC air levels equal to or lesser than outdoor concentrations. If these materials were a source of airborne contamination, then indoor TVOC levels should exceed outdoor concentrations on the date of monitoring.

A source of TVOCs, independent of floor tiles however, was identified during the BEHA sampling. In an effort to reduce noise from sliding chairs, tennis balls are sliced open and placed on chair legs (see Picture 15). A newly opened tennis ball had an initial TVOC concentration inside the ball of 15 ppm, which eventually dropped to 4 ppm after several minutes. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and to off-gas TVOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix A (NIOSH, 1998).

A potential source for drawing in unfiltered air from the outdoors was identified in the form of condensation drainpipe holes in the back of each univent cabinet. Each of these drains penetrates the rear wall of the univent cabinet (see Picture 13) and exits the building through the exterior univent fresh air intake section. In some cases, outdoor light could be seen between the pipes and the cabinet (see Picture 14), which indicates an air space. Since this hole exists above the filter in univents, operating fans can draw unfiltered air from the univent fresh air opening as well as outdoor pollutants (e.g., pollen, dirt and dust).

Concerns were also raised about possible groundwater contamination from alleged dumping in the wetland behind the HES as being the source of indoor air quality complaints. A number of different conditions appear to rule out hazardous waste contamination as the root of the problems in this building:

1. Ground water samples found no measurable levels of VOCs in wells drilled outside the HES structure or beneath the slab (EH&E, 2000);
2. Moisture monitoring of the cement slab did not find unusual amounts of moisture in the slab (CEC, 1991; EH&E, 2000);
3. HES is located on a slight rise above the swamp. Groundwater flooding up to the slab of the HES has not been reported as a reoccurring problem. Building occupants did report that the ground in a playing field to the northeast of the HES could become marshy during spring months;
4. An examination of topographical maps of the area indicate that groundwater would be expected to flow in an easterly direction away from the HES (see Map 2). The wetlands serve as the headwaters for the Sudbury River, which flows in an easterly direction. Along the northern edge of the wetland, along Flanders Road, is an elevation that would direct groundwater in a southerly direction toward Cedar Swamp Pond. A number of brooks feed into Cedar Swamp Pond (Rutters Brook, Picadilly Brook, Denny Brook and Jackstraw Brook) from a westerly direction. Therefore, if hazardous material were dumped in the wetland, the direction of groundwater flow should carry the contamination in an easterly direction, away from the grounds of the HES.

Based on available information, it is unlikely that contaminated groundwater is penetrating into the interior of the building through the floor.

The main office and teachers' lounges have photocopiers. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992). School personnel should ensure that local exhaust ventilation is activated while equipment is in use to help reduce excess heat and odors in these areas.

A number of classrooms contained upholstered furniture. Upholstered furniture is covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent, dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, M.A., 1994). It is also recommended that upholstered furniture (if present in schools), be professionally cleaned on an annual basis or every six months if dusty conditions exist outdoors (IICR, 2000).

Accumulated chalk dust was noted in several classrooms. Chalk dust is a fine particulate, which can be easily aerosolized and is an eye and respiratory irritant. Several classrooms contained dry erase boards and dry erase markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs (e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Cleaning products were found in a number of classrooms and insecticides have reportedly been brought in by individuals. Cleaning products and insecticides contain chemicals that can be irritating to the eyes, nose and throat and should be kept out of reach of students. A bottle of pyrethrin-based insecticide was seen in one classroom. Pyrethrins have been associated with cross sensitivity with individuals who have ragweed allergy (US EPA, 1989). Applicators of this product should be in full compliance with the federal and state rules and regulations that govern pesticide use, including posting and notification requirements (333 CMR 13.10). Under no circumstances should untrained personnel apply this material. This product should not be applied prior to or during school hours. If application must be done during the week, this material should be applied shortly after the day ends, in order to give the applied areas ample time to dry. Under current Massachusetts law (effective November 1, 2001), the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass. Act, 2000). A copy of the IPM guide is attached as Appendix B. Unlabeled/poorly labeled spray bottles were also noted. Products should be kept in their original containers, or should be clearly labeled as to their contents, for identification purposes in the event of an emergency.

Also of note was the amount of materials stored inside classrooms. In several areas, items were observed piled on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, and boxes) make it difficult for custodial staff to clean in and around these areas. Dust can be irritating to the eyes, nose and respiratory tract. For this reason, items should be relocated and/or cleaned periodically to avoid excessive dust build up. In addition, a number of exhaust vents in classrooms were noted with accumulated dust. If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize accumulated dust particles.

Building occupants report heavy accumulation of dirt in rear hallway entrances from students entering the building after recess. The playground is grass, sand and dirt, which becomes muddy during wet weather. If tracked-in, this dirt can become a source of airborne particulates once dried.

Conclusions/Recommendations

The Westborough School Department has clearly taken a number of positive steps to remediate the ongoing, perceived indoor air quality concerns at the HES. The majority of these actions have served to improve the conditions in the building. The repair of the roof, paving of the interior courtyards, reversal of the pressurization of the building and improvement of univents filters will all help to decrease sources of materials that can adversely impact indoor air quality. Some conditions concerning the design of the building warrant further attention. The configuration of the exterior wall systems, installed when the school was constructed, appears to allow for moisture to accumulate in the fresh air intake hole for each univent. The lack of insulation within each univent to prevent condensation generation may also contribute to the overall moisture concentrations in the HES. Addressing both of these conditions as well as other point sources of pollutants in classrooms detailed in this report should serve to further improve indoor air quality.

In order to address the conditions listed in this assessment, the recommendations made to improve indoor air quality are divided into short-term and long-term corrective measures. The short-term recommendations can be implemented as soon as practicable. Long-term solution measures are more complex and will require planning and resources to adequately address overall indoor air quality concerns.

In view of the findings at the time of this assessment, the following recommendations are made:

Short Term Recommendations

1. Monitor classroom walls that have had efflorescence for water build up behind classroom paint. If paint bubbling occurs, remove the damaged surface and clean with an appropriate antimicrobial agent. If water penetration is persistent, see Long Term Recommendations.
2. Remove all blockages from univents and exhaust vents.
3. Apply a heavy coat of floor wax over blemished floor tile to create a barrier. Continue with plans to examine options for removing blemishes, which may include replacing floor tiles.
4. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy independent of classroom thermostat control.
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

6. Move plants away from univents in classrooms. Ensure all plants are equipped with drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary. Consider reducing the number of plants.
7. Relocate or place tile or rubber matting underneath water cooler(s)/fountains.
8. Remove accumulated scale and corrosion from the surface of drip pans.
9. Repair the windows in classroom 105.
10. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
11. Clean and maintain aquariums and terrariums to prevent bacterial/mold growth.
12. Clean upholstered furniture on the schedule recommended in this report. If not possible/practical, remove upholstered furniture from classrooms.
13. Discontinue the use of tennis balls on chairs to prevent latex dust generation.
14. Store cleaning products properly and out of reach of students. Store flammables in a flameproof cabinet.
15. Have a chemical inventory done in all storage areas and classrooms. Properly store flammable materials in a manner consistent with the local fire code. Discard hazardous materials or empty containers of hazardous materials in a manner consistent with environmental statutes and regulations. Label chemical containers with the chemical name of its contents. Follow proper procedures for storing and securing hazardous materials.
16. Obtain Material Safety Data Sheets (MSDS) for chemicals from manufacturers or suppliers. Maintain these MSDS' and train individuals in the proper use, storage and

protective measures for each material in a manner consistent with the Massachusetts Right-To-Know Law, M.G.L. c. 111F (MGL, 1983).

17. Clean chalkboards and trays regularly to avoid the build-up of excessive chalk dust.
18. It is highly recommended that the principles of integrated pest management (IPM) be used to rid this building of pests. A copy of the IPM recommendations are included with this report as Appendix B (MDFA, 1996).
19. To reduce tracked-in dirt, consider replacing the hallway carpet with a rubber link mat that can be easily removed for daily wet mopping.

Long Term Recommendations

1. Due to the apparent configuration of the curtain wall/drainage plane system, measures should be taken to minimize water contact with the exterior walls. Removing trees outside of the kindergarten classrooms and foliage close to exterior walls is recommended.
2. In order to remove moisture from curtain wall/drainage plane system penetrating into the univent fresh air intake hole, it is recommended to install a duct connecting the fresh air intake grill to the base of each univent (see Figure 3). The duct should be constructed of a material that is water/corrosion resistant and is installed in a manner to facilitate moisture drainage and drying of surrounding brickwork.
3. A ventilation engineer should be consulted to ascertain the appropriate methods that may be employed to reduce or eliminate condensation-generation within univents during the cooling season.
4. Increase the pitch of univent drip pans to enhance drainage.

5. Insulate the surface of drip pans not in contact with condensation with an appropriate material.
6. If water penetration/efflorescence observed in various areas of the building returns, consideration should be given to having a building engineer examine each damaged area with the intent to recommend possible drainage plane remediation strategies.

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Figure 2
Moisture Accumulation within Univent Fresh Air Intake Vent from Exterior Wall Drainage Plane

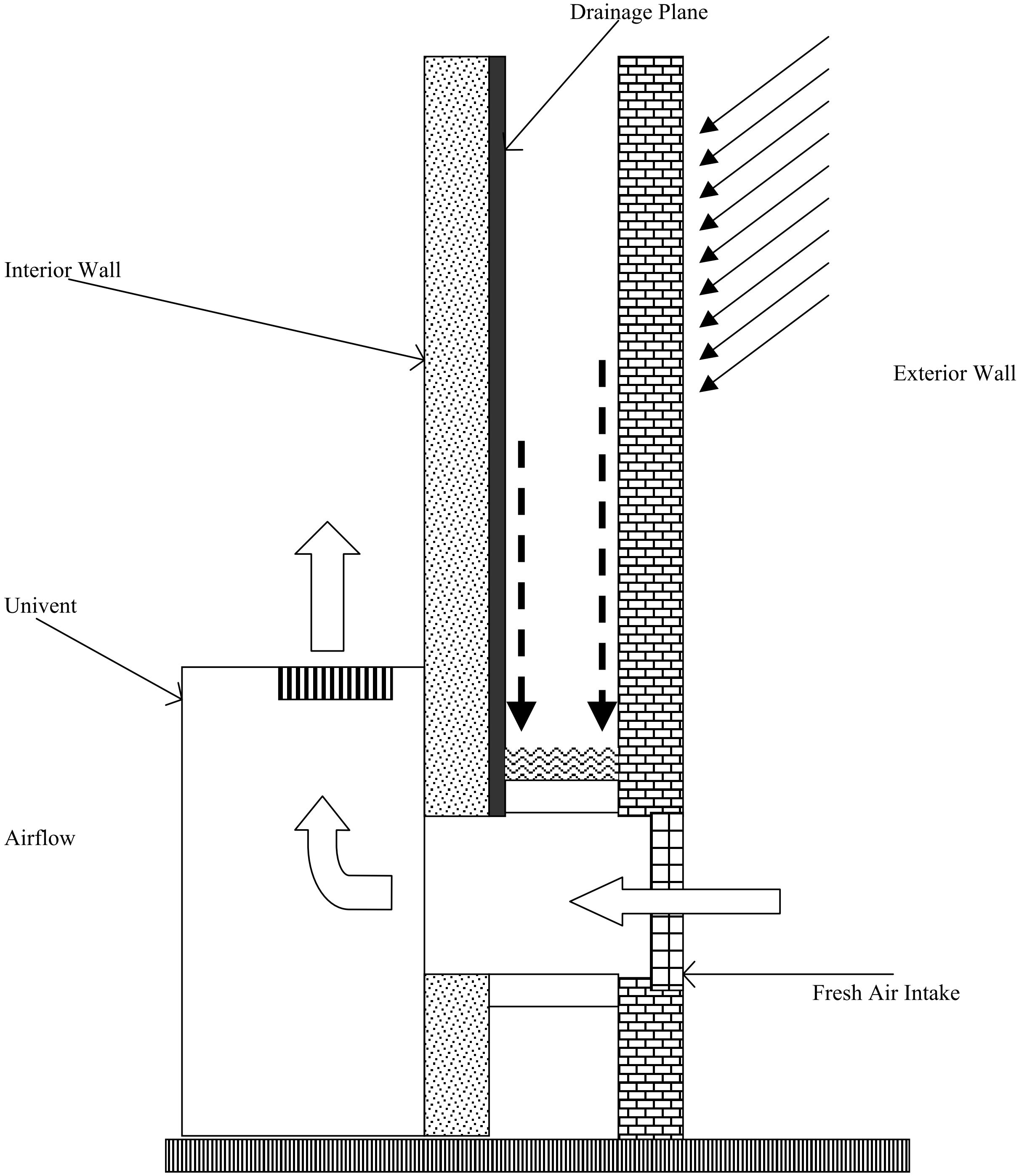
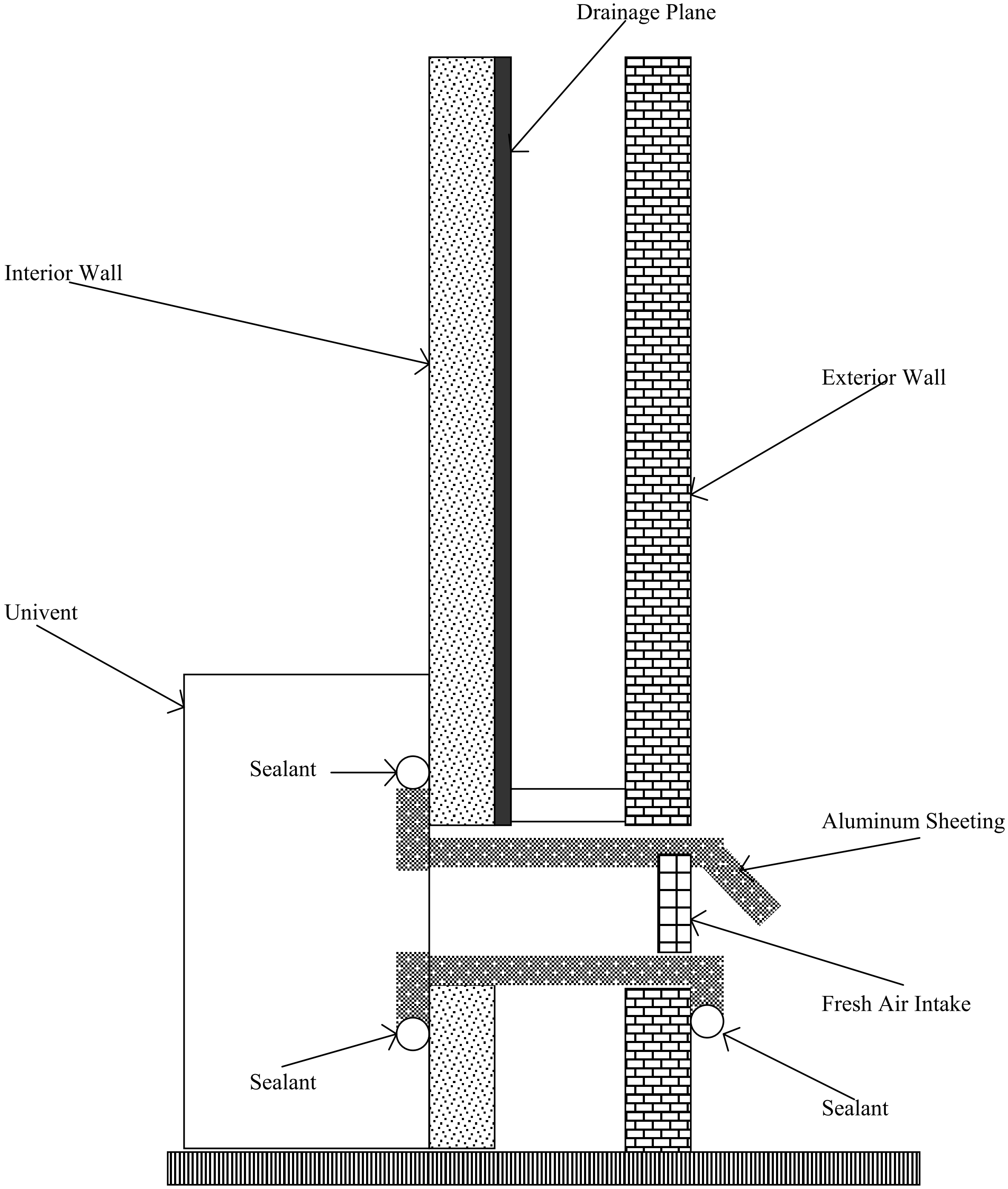
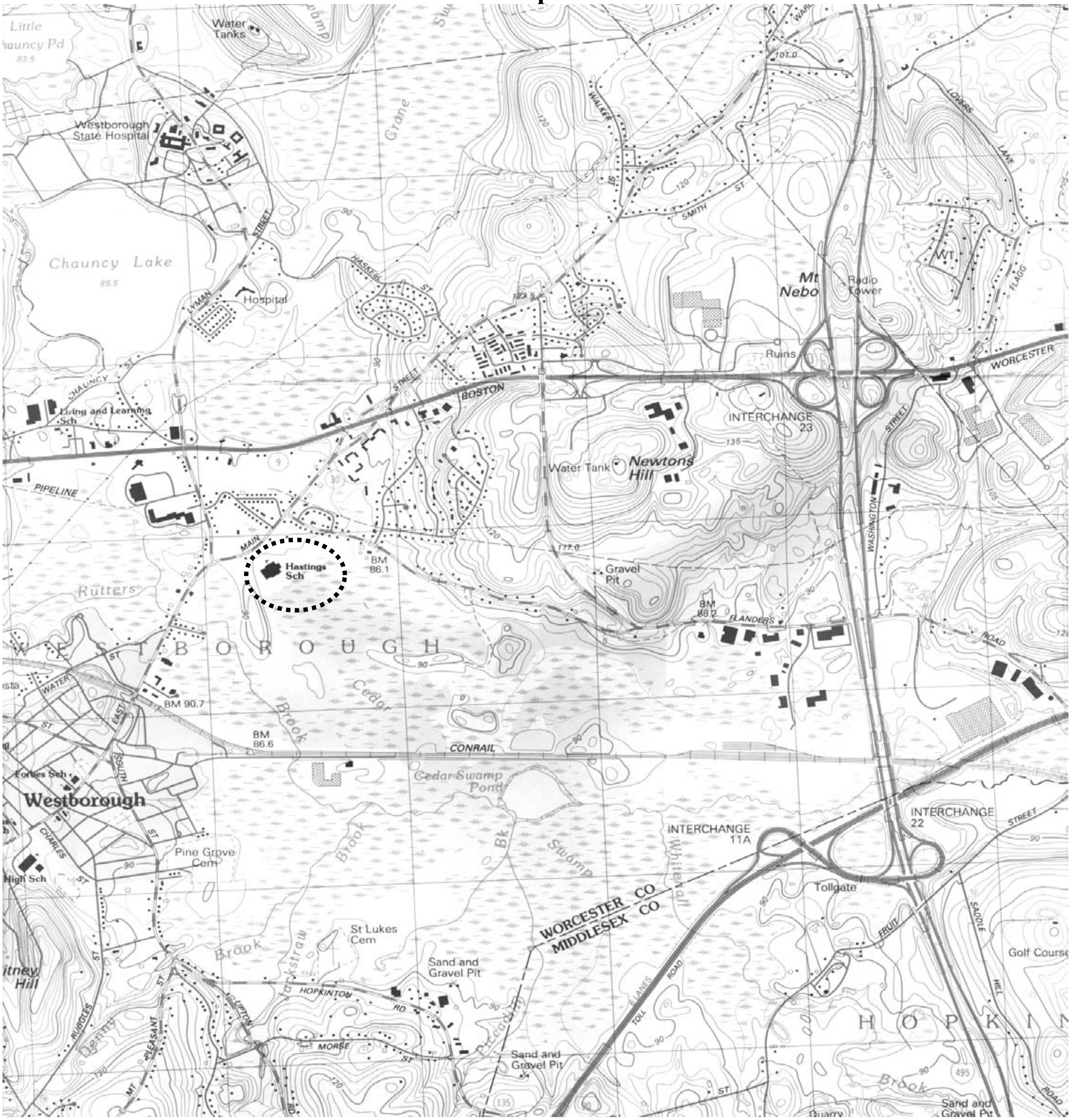


Figure 3
Sealing of Univent Fresh Air Intake Vent from Exterior Wall Drainage Plane



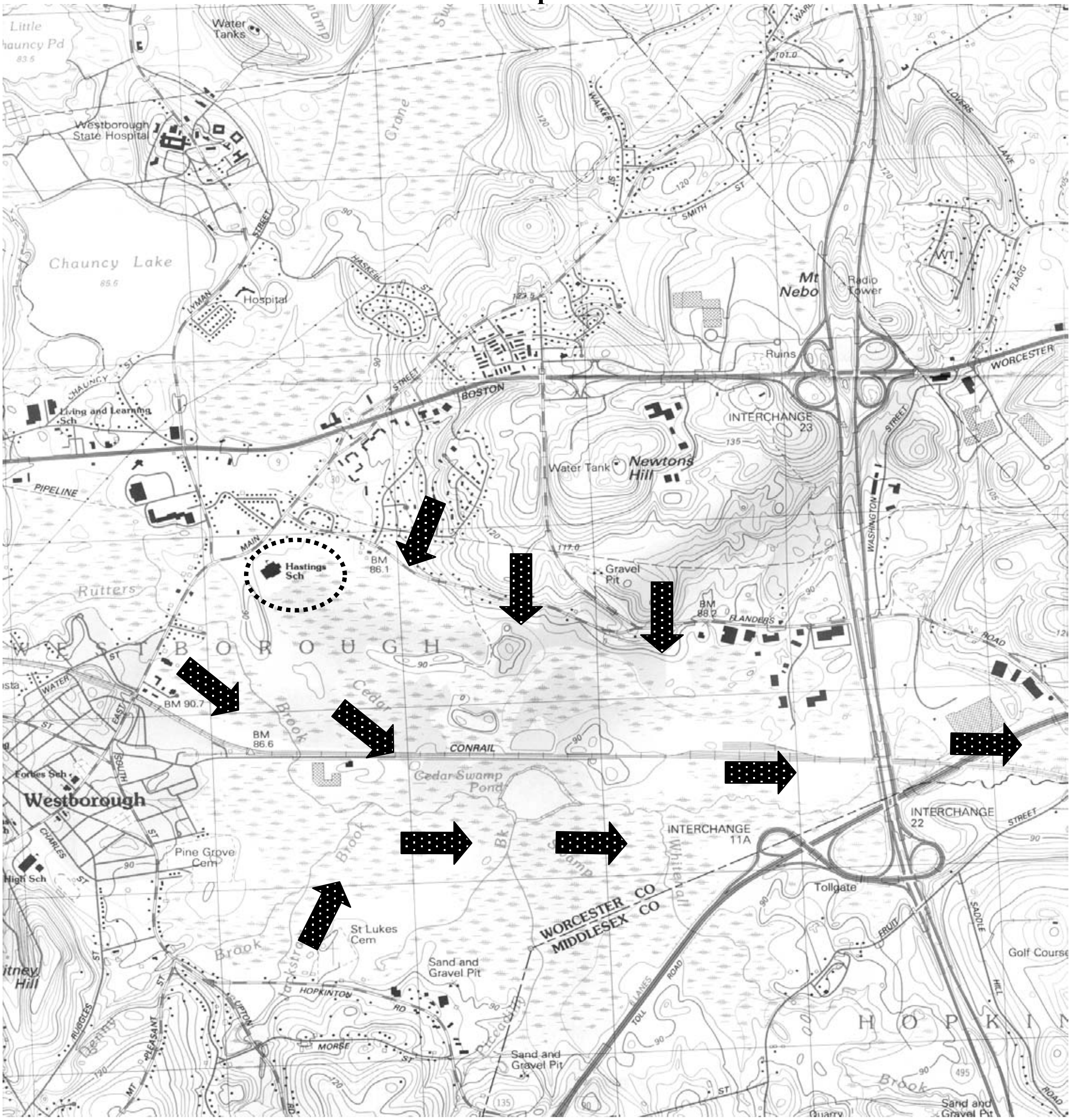
Map 1



North at Top

Topographical Map of Area Surrounding the Hastings Elementary School

Map 2



North at Top

Expected Groundwater Flow Toward the Sudbury River (Arrows Note Direction)

Picture 1

Pod Courtyards Were Paved With Concrete

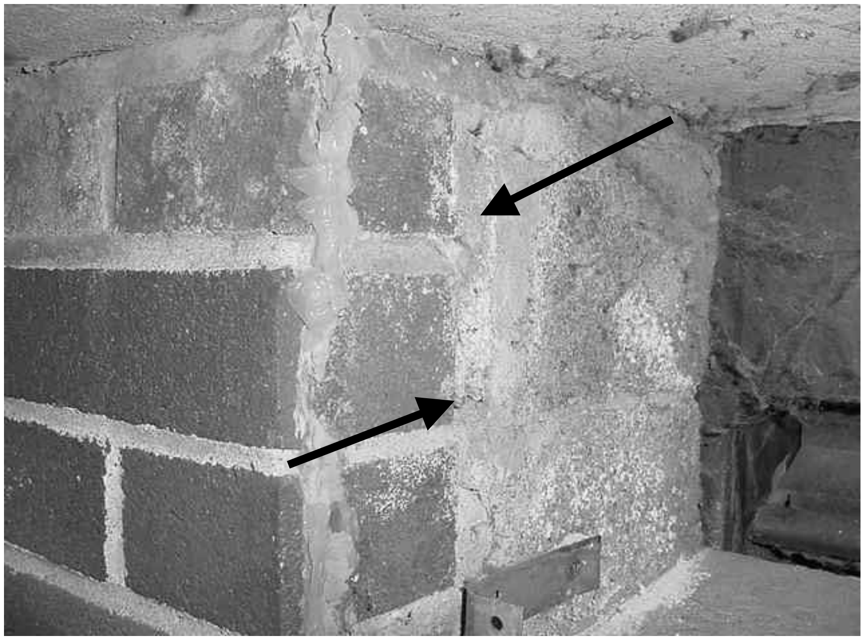
Picture 2

Univent Blocked With Desks and Paper

Picture 3

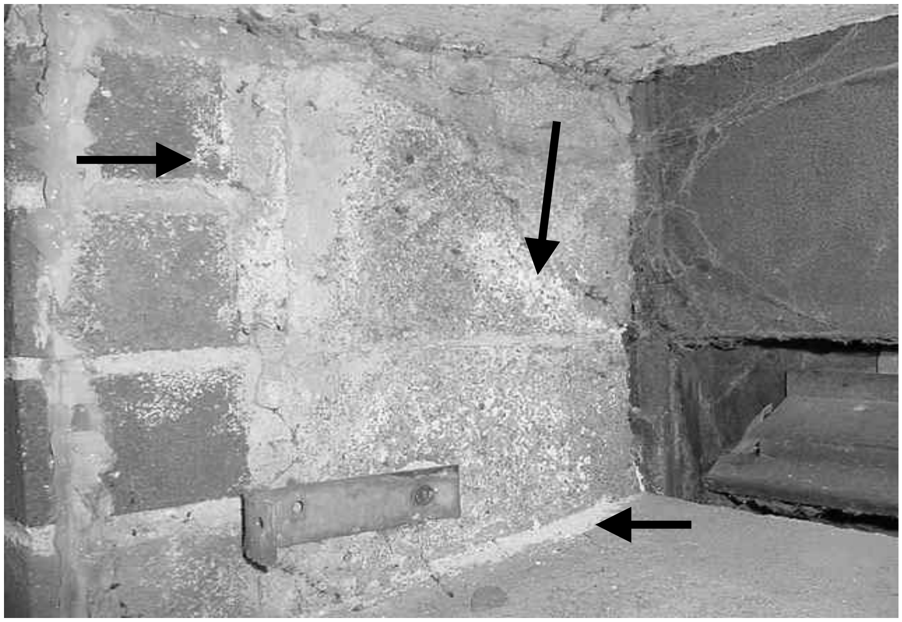
Exhaust Vent in Closet of Classroom

Picture 4



Airspace Between the Exterior Wall and Drainage Plane - Sealed With Concrete

Picture 5



The Interior Wall of Brick Forming the Fresh Air Intake Opening Coated with Efflorescence, Indicating Water Penetration

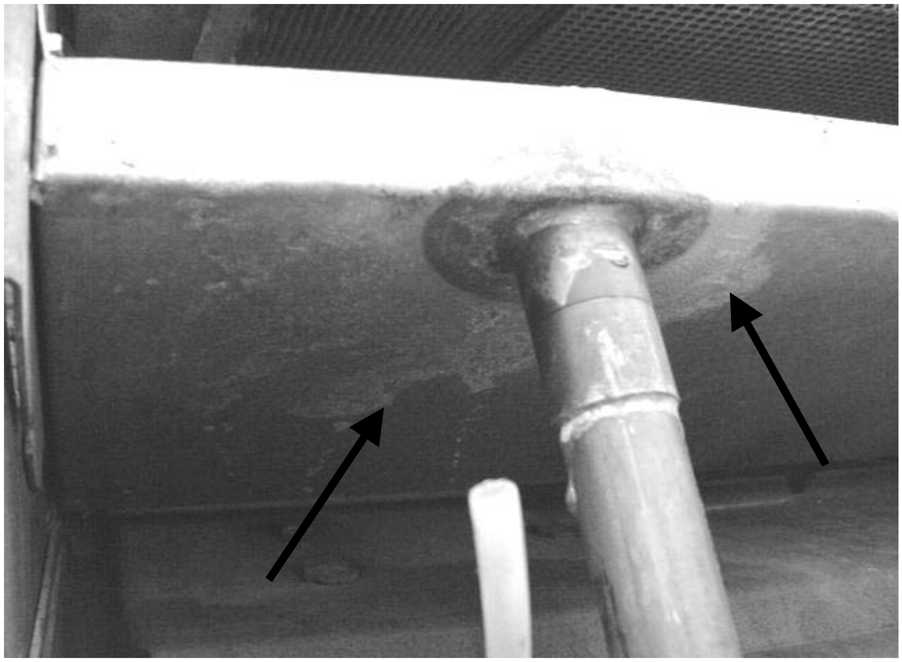
Picture 6

Hole Cut For the Installation of An Exhaust Vent In An Interior Courtyard

Picture 7

Corrosion on Surface of Drip Pans

Picture 8

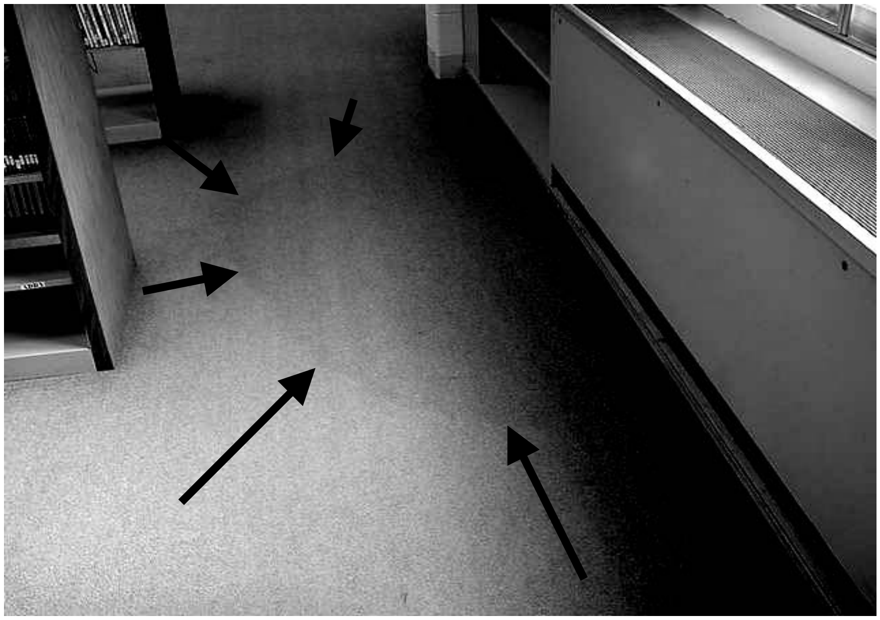


Signs of Dried Condensation Noted on the Underside of Drip Pans

Picture 9

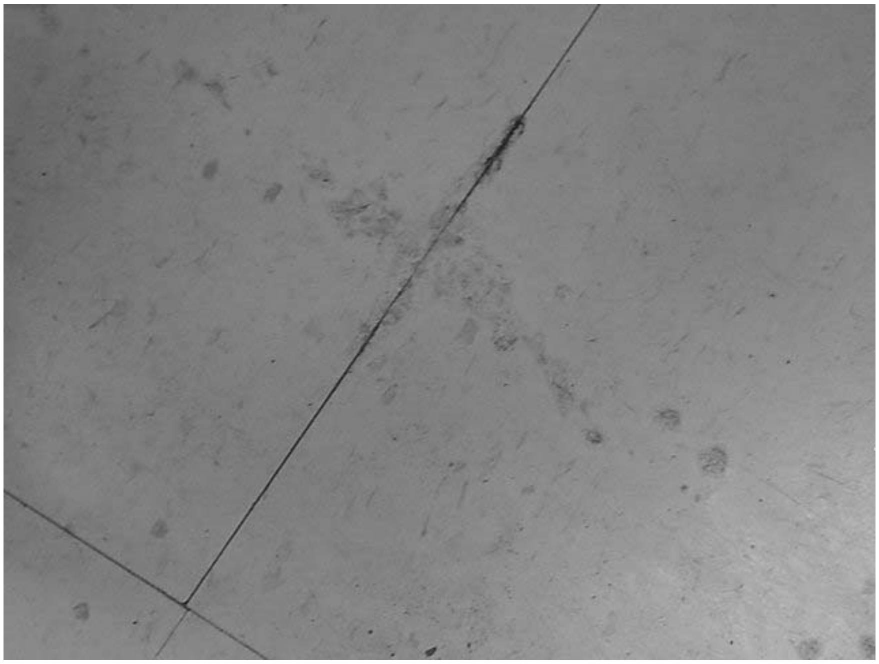
Signs of Dried Condensation on Pipe Insulation inside Univent Control Chambers

Picture 10



Stain On Library Carpet

Picture 11

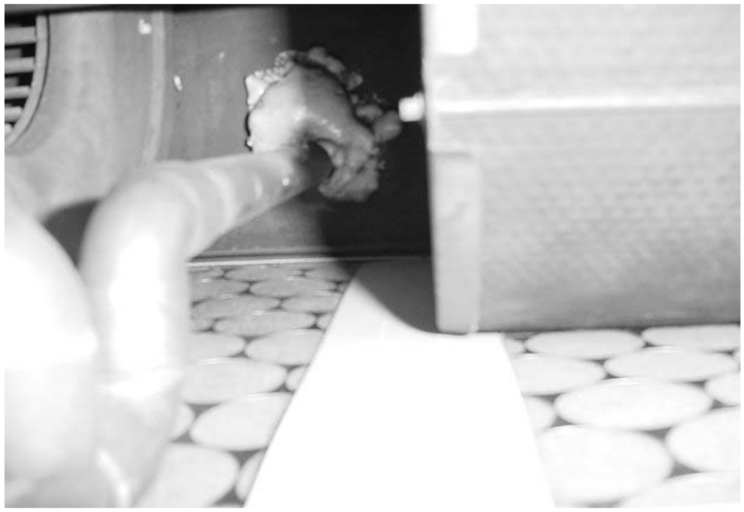


Seeping From Seams in Classroom Floor Tile

Picture 12

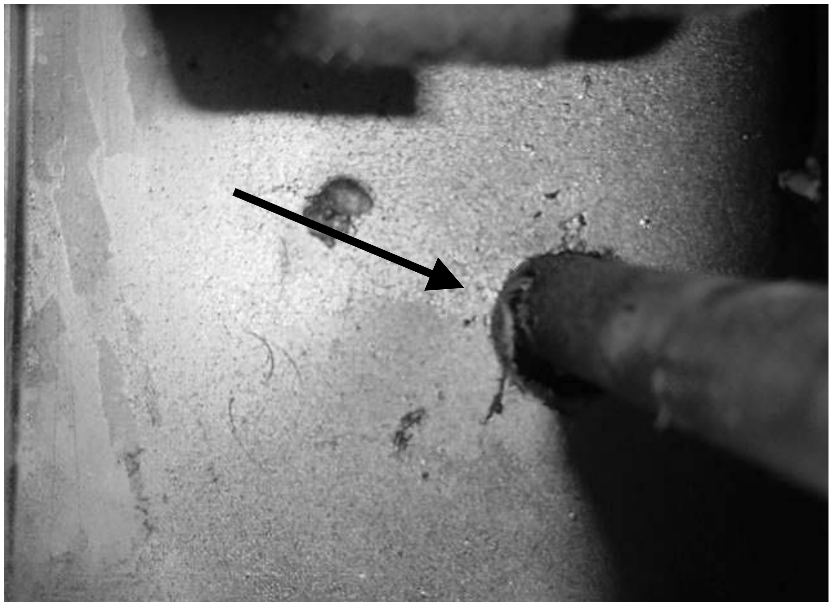
Seeping From Seams in Classroom Floor Tile

Picture 13



**Univent Condensation Drain Passing Through the Rear Cabinet Wall.
Note that This Drainpipe is above the Filter and below Univent Fans**

Picture 14



Light From Univent Condensation Drain Cabinet Hole, Indicating an Air Pathway

Picture 15

Tennis Balls Are Sliced Open and Placed on Chair Legs

TABLE 1

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	380	63	42					Weather conditions: cool, overcast, light breeze
Gym	560	71	43	3	No	Yes	Yes	2 ceiling mounted AHUs, 2 wall mounted exhaust grills
Art Storage	613	71	40	1	No	Yes	Yes	
204	786	72	41	16	Yes	Yes	Yes	Staining on floor tiles, plant on univent, items blocking univent return, stuffed animals, upholstered furniture, area rug, spray cleaner under sink
205	660	72	39	15	Yes	Yes	Yes	Degreaser on sink countertop, door open
206	639	72	41	13	Yes	Yes	Yes	Items obstructing univent airflow, 1 water stained CT
ESL	949	73	58	8	No	Yes	Yes	Interior classroom
Occupational Therapy	954	73	37	2	No	Yes	Yes	
Speech Room	840	73	37	1	No	Yes	Yes	Exhaust obstructed by door

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
2nd Grade Planning Room	762	72	36	0	No			Ceiling vent-no airflow
202	682	73	40	19	Yes	Yes	Yes	
203	702	73	41	19	Yes	Yes	Yes	Items in front of univent return, cleaning product/flammables under sink
Boy's Restroom (near gym)					No	Yes	Yes	Passive intake
Girl's Restroom (near gym)					No	Yes	Yes	Passive intake
101	652	73	40	12	Yes	Yes	Yes	Exhaust weak, door open
102	680	73	40	18	Yes	Yes	Yes	Flowering plants on univent
103	740	71	41	16	Yes	Yes	Yes	Exhaust weak
106	664	72	42	15	Yes	Yes	Yes	Spaces-sink countertop/backsplash
105	616	72	41	18	Yes	Yes	Yes	2 windows broken (upper)

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide - < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems
Temperature - 70 - 78 °F
Relative Humidity - 40 - 60%

TABLE 3

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
104	705	72	41	21	Yes	Yes	Yes	2 plants-flowers, cleaning product under sink
Mrs. Kitteredge Office	694	74	39	2	Yes			Ceiling vent-no airflow, dry erase board
Mrs. Shaw Classroom	683	75	37	1	Yes	Yes	Yes	Dry erase board, sand box, cut vegetables on table, cleaning products
Speech Room	753	76	36	0	No	Yes	Yes	Exhaust off, plant
Pre-school 3	825	76	38	6	Yes	Yes	Yes	Dry erase board, water table, sand box
K-1	702	74	38	19	Yes	Yes		Clay items drying on univent, spaces-sink countertop/backsplash, cleaning product under sink, accumulated stuff, window and door open, exhaust in restroom
Restrooms – shared between K-1/K-2					No	Yes	Yes	Passive intake
K-2	686	74	38	17	Yes	Yes		Univent return blocked by table, spaces-sink countertop/backsplash, cleaning product under sink

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 4

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
201	789	73	39	20	Yes	Yes	Yes	Univent return blocked, exhaust weak, spaces-sink countertop/backsplash, cleaning product under sink, 2 plants, dry erase board, accumulated stuff
Library	682	72	36	29	Yes	Yes (2)		Terrarium, carpet, 8 computers
Library Office	898	73	37	1	No	Yes	Yes	Exhaust weak, carpet, spaces-sink countertop/backsplash, strong pungent odor from under sink (glue), feather dusters under sink, complaints of afternoon fatigue in room
Reading Room	559	70	42	9	Yes	Yes	Yes	Exhaust weak, dry erase boards, spaces - sink countertop/back-splash (warping), cleaners/pesticide under sink, floor "spots", accumulated stuff, condensation between windows
Reading Room Restrooms				0	No	Yes	Yes	Passive intakes, floor drains
Reading Room Office	634	70	41	0	No	No	Yes	

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 5

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
404	704	72	41	19	Yes	Yes	Yes	Items on top of univent-return blocked by cart, exhaust weak, chalk dust, dry erase board, spaces-sink countertop/backsplash, games/cleaning product/paper towels under sink, condensation between windows
Women's Restroom					No	Yes	Yes	Passive intake, floor drain, thermostat Water cooler over carpet in hallway outside
Cafetorium	777	72	40	~145	Yes	Yes	Yes	Aquarium, 4 photocopiers in hallway outside
Teacher's Workroom	933	73	37	0	No	Yes	Yes	Lamination machine, carpet
Stage Area	653	73	37	7				Dry erase board, efflorescence
402	823	75	40	44	Yes	Yes	Yes	Spaces-sink countertop/backsplash chalk dust
301	779	74	39	24	Yes	Yes		Univent return blocked by bookcase, spaces-sink countertop/backsplash,

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 6

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
								accumulated stuff
Main Office	1276	74	38	2	No	Yes	Yes	Carpet
Main Office Workroom				0	No	Yes	No	Water cooler on carpet, toner, cleaning product, food
Nurse's Office	935	74	37	2	No	Yes		Exhaust in restrooms-on
406	908	74	39	18	Yes	Yes	Yes	Exhaust weak, spaces-sink countertop/backsplash, dry erase board, 2 plants
405	854	73	38	15	Yes	Yes	Yes	Exhaust weak, univent very blocked, spaces-sink countertop/backsplash, cleaning product/dry erase board cleaner on counter, dry erase board, 2 plants
K-3	873	73	39	24	Yes	Yes		Univent return blocked, restroom exhaust-light switch activated, spaces-sink countertop/backsplash, condensation between windows
3rd Grade Planning Room	806	73	37	0	No			Ceiling vent-no airflow, under sink: cleaning product/pesticide,

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 7

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
								artificial snow, spaces-sink countertop/backsplash
Computer Lab	849	74	39	1	No			Ceiling vent-no airflow, 12 computers, personal fan, door open, spaces-sink countertop/backsplash, cleaning product/feather duster under sink
401	745	73	38	6	Yes	Yes	Yes	Spaces-sink countertop/backsplash paper under sink, dry erase board, floor tile mastic
302	738	73	38	10	Yes	Yes	Yes	Spaces-sink countertop/backsplash cleaning product under sink, window open, dry erase board, plant
303	791	73	39	19	Yes	Yes	Yes	Exhaust weak, dry erase board, spaces-sink countertop/backsplash
304	667	73	38	13	Yes	Yes	Yes	Spaces-sink countertop/backsplash dry erase board
306	708	72	39	14	Yes	Yes	Yes	Univent return blocked by tent, spaces-sink countertop/backsplash, cleaning product under sink, chalk dust, dry erase board, accumulated

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 8

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 15, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
								stuff
305	595	73	38	0	Yes	Yes	Yes	Spaces-sink countertop/backsplash
403	860	74	40	0	Yes	Yes	Yes	Spaces-sink countertop/backsplash Chalk dust, dry erase board, aquarium, accumulated stuff

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 9

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 16, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Outside (Background)	388	45	55					Weather conditions: cool, overcast, light breeze
Main Office	813	70	49			Yes	Yes	
Main Hallway	741	72	47			*	*	
K1	625	71	45	11		Yes	Yes	Exhaust off, door open
K2	685	72	45	18		Yes	Yes	Door open
K3	676	72	44	22		Yes	Yes	Supply blocked by box, door open
406	706	72	45	20		Yes	Yes	
405	721	72	42	17		Yes	Yes	Supply off
Reading Room	562	72	40	13				
404	876	72	40	17				
Library	632	72	41	17		Yes	Yes	

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 10

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 16, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
401	818	72	43	15	Yes	Yes	Yes	
401 Computer Room	960	74	43	0	No	Yes	Yes	Door open
402	766	73	41	25	*	Yes	Yes	
403 Hallway	750	74	42	0	Yes	Yes	Yes	
403	750	74	42	21	Yes	Yes	Yes	
303	866	74	41	17	Yes	Yes	Yes	Door open
302	725	73	40	16	Yes	Yes	Yes	Door open
301	855	73	40	23	Yes	Yes	Yes	Door open
304	636	72	40	9	Yes	Yes	Yes	Door open
304 Hallway								Gym odor
305				0	Yes	Yes	Yes	Office supply

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 11

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 16, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
306	644	72	41	9	*	Yes	Yes	
Gym	570	72	41	40+	Yes	Yes	Yes	Rubber odor, outside door open
206	588	73	42	1	Yes	Yes	Yes	Clay items drying on univent, spaces-sink countertop/backsplash, cleaning product under sink, accumulated stuff, window and door open, exhaust in restroom
205	625	72	40	15	Yes	Yes	Yes	
204	635	72	41	10	Yes	Yes	Yes	Supply blocked, door open
201	682	72	42	18	Yes	Yes	Yes	Supply blocked, door open
202	590	72	41	10	Yes	Yes	Yes	
203	688	72	42	19	Yes	Yes	Yes	Supply blocked, door open
103	606	72	41	17	Yes	Yes	Yes	Supply blocked, door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 12

Indoor Air Test Results – Hastings Elementary School, Westborough, MA – November 16, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
102	684	73	42	19	Yes	Yes	Yes	
101	718	74	43	18	Yes	Yes	Yes	Door open
104	566	73	40	18	Yes	Yes	Yes	Supply blocked, door open
105	577	72	41	17	Yes	Yes	Yes	
106	579	73	41	17	Yes	Yes	Yes	Door open
Nurse's Office	805	74	40	1	No	Yes	Yes	Exhaust vent in restroom

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 13
TVOC Air Test Results
Hastings Elementary School, Westborough, MA
January 10, 2002

Location	**Total Volatile Organic Compound [in parts per million (ppm)]**
Outdoors	0.3
406	0.3
405	0.3
404	0.3
403	0.3
402	0.3
401	0.3
301	0.3
302	0.3
303	0.3
304	0.3
305	0.3
306	0.3
Gymnasium	0.2
Art Room	0.2
206	0.3
205	0.3
204	0.3
203	0.3
202	0.3
201	0.3
101	0.3
102	0.3
103	0.3
104	0.3
105	0.3